

Vital Signs Monitoring - Geologic Attributes and Measures

Draft –6/7/04 by Lisa Norby, Julia Brunner, Hal Pranger, Dave Steensen, Greg McDonald

Review and comment by Jon Riedel, Vicki Ozaki, Ron Kerbo, Lindsey McClelland, Andrew Valdez

GEOLOGIC ATTRIBUTE	RESOURCE MONITORED	JUSTIFICATION	COMMENTS (how monitoring relates to the ecosystem)	SPECIFIC MEASURES
Windblown (Aeolian) Features and Processes	dunes, loess deposits (wind blown silt), desert surface crusts, wind, dust storms	Aeolian processes are a natural phenomenon, but their affects may be exacerbated by human actions such as cultivation, overgrazing, and urbanization. Changes in dune morphology or position may indicate variations in climate, wind velocity and direction, or disturbance by humans. Changes in wind-shaped surface morphology and vegetation related to desertification, drought, aridification, and wet cycles (fire can also affect vegetation cover) are important gauges of environmental change in arid and semi-arid regions. Sand that has become stabilized by vegetation can become mobilized and greatly change the nature of the landscape and ecosystem.	Dust storm frequency, duration, and magnitude may be indicative of climate change and changes in windspeed and direction. Dust storms are natural events, but the amount of sediment available for transport may be related to surface disturbances such as overgrazing, ploughing, vegetation removal, fire, and urbanization. Dust in the atmosphere can influence weather patterns and can be a human health concern. Airborne deposition of particles is also a concern for many parks because it can result in changes in soil, sediment, and water chemistry, modify vegetation communities, and diminish visibility. The loss or encroachment of vegetation on sand deposits greatly affects dunes stability and ecosystem diversity.	Size, shape, and position of sand dunes and loess deposits; volume of sediment moved; wind speed and direction; groundwater levels; date, time and duration of wind storms; wind speed and direction; visibility monitoring; sand moisture
Glacial Features and Processes	glaciers, glacial lakes, glacial dams, glacier movement (advance and retreat of glaciers), frozen ground activity; periglacial features; subsurface temperature regimes	Glaciers are highly sensitive, natural, large-scale indicators of hydrologic and energy balance at the Earth's surface in polar regions and high altitudes. Their capacity to store water for extended periods of time exerts significant control on the surface water cycle, and their presence exerts a powerful influence on nearby physical and biological processes. The advance and retreat of glaciers creates hazards to nearby human structures and communities through avalanches, slope failure, and catastrophic outburst floods from lakes beneath glaciers and those dammed by ice and glacial moraines.	Glaciers grow or diminish in response to natural climatic fluctuations. The size and volume of mountain glaciers has decreased throughout the world over the past 150 years, providing strong evidence of global warming and decreasing precipitation. Glaciers buffer ecosystems from extreme low flow periods, affecting baseflows and the timing and amount of runoff.	Glacier area and volume, position of terminus and margins, mass balance (winter, summer, annual), equilibrium line altitude, repeat photography (using fixed photo points), glacial runoff (by individual glacier and by watershed), glacier surface features (ice falls, crevasses, ponds, moraines etc)
Caves and Karst Features and Processes	Caves (karst and non-karst), karst landscapes / systems, sedimentation processes, water quality, water chemistry	<p><u>Key legal and policy mandates:</u> Federal Cave Resource Protection Act, its regulations, and NPS Management Policies (karst – §4.8.1.2 and caves – §4.8.2.2)</p> <p>Cave and karst systems are sensitive to many environmental factors.</p> <p><i>Inappropriate construction.</i> The construction of poorly</p>	Karst is a type of landscape found in carbonate rocks (limestone, dolomite, marble) or evaporites (gypsum, anhydrite, rock salt) and is typified by a wide range of closed surface depressions, a well-developed underground drainage system, and a paucity of surface streams. The highly varied interactions among chemical, physical and	Temperature, pH, humidity, gas concentration, water chemistry (Ca, Mg, Na, Cl, HCO ₃ , SO ₄), water quality, temporal changes in cave deposits (speleothems), biota (species and distribution)

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		<p>designed structures in caves such as expanded entrances, elevator shafts, and gates have led to the destruction of cave resources through the interference with air flow patterns and animal movement. For example, a “bat-unfriendly” cave gate will inhibit the daily passage of bats into and out of the cave, often resulting in the abandonment of the cave by the bats altogether. Because of reduction in available habitat, over 50% of the bat species in the United States are in significant decline or are endangered.</p> <p><i>Excessive contamination.</i> Urbanization is creeping up on parks including those with cave resources. Water, which is the building force of most caves, carves cave passages and sculpts unique speleothems by dripping and seeping year after year in exactly the same way. Cave species organize their existence around these water sources and depend upon them for their survival. Increased human activity, including NPS activity, such as agriculture and road network expansion threatens the quality and the quantity of the water that feeds and sustains the cave system.</p> <p><i>Loss and Destruction of Resources.</i> Unregulated or illegal access to caves has resulted in the destruction of cave resources. Vandals steal or deface unique cave formations and archaeological specimens. In addition, recreational visitors inadvertently import exotic species (e.g., spores, fungi), which affects the integrity of the biotic web, and oils, dust, and lint, which build up on speleothems affecting the survival of cave species and speleothem formation.</p>	<p>biological processes have a broad range of geological effects including dissolution, precipitation, sedimentation and ground subsidence. Diagnostic features such as sinkholes, sinking streams, caves, and large springs are the result of the solutional action of circulating groundwater. Caves contain a variety of dissolution features, sediments and speleothems (deposits with various forms and mineralogy, chiefly calcite), all of which may preserve a record of the human, paleontological, geological, and climatic history of the area and provide habitat for a variety of life forms including microorganisms living in extreme environments. Caves also form in non-karstic environments and can include sea or littoral caves, tectonic fractures and lava tubes.</p>	
Geothermal Features and Processes	hot springs, geysers, fumaroles, mineral precipitates and formations, mudpots, hydrophylic biotic communities, water quality, and water chemistry	<p><u>Key legal and policy mandates:</u> Geothermal Steam Act (and amendments), NPS Management Policies §4.8.2.3.</p> <p>Geothermal features are a reflection of thermal processes that occur beneath the Earth’s surface, often at great depth. The Geothermal Steam Act Amendments of 1988 (P. L. 100-443) require that the</p>	<p>There is a risk that surface geothermal features (e.g., hot springs, mineral pools, geysers) may be altered or permanently lost due to geothermal development in and around parks. The impacts of geothermal resource development on volcanic (non-hydrothermal) features are not well understood, and care must be taken to prevent irreversible impacts on these as well.</p>	<p>Water temperature, discharge rate, water chemistry (F⁻, Cl⁻, SO₄, Si, HCO₃, pH), thermal feature and discharge gas chemistry, chloride flux, heat flow</p>

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		National Park Service establish and maintain a monitoring program for all units of the National Park System which have thermal features qualifying as “significant” (sixteen NPS units were identified in the Act). The Act requires the NPS to establish a research and monitoring program to collect and assess data on these features.	Geothermal processes can also create, perpetuate, or impact existing surface features and environments where the waters are discharged on to the surface. In addition, geothermal systems are often sites of intensive biological activity (bacteria, viruses, fungi, and protozoa).	
Volcanic Features and Processes	volcanoes, lava tubes, vents, lava flows, pyroclastic flows, lahars, tephra, volcanic gases	Volcanism is a natural phenomenon that is not influenced by human actions. Instead, the effects of the eruptions are a primary concern for human health and safety and potential damage to natural and cultural resources and human developments. Natural hazards associated with eruptions of active volcanoes pose a threat to approximately 10% of the world’s population.	Volcanic eruptions can have profound effects on the environment through heat, impact, deposition, and gas chemistry, on scales ranging from local to regional. Significant topographic and fluvial changes often occur, and surface ecosystems may be sterilized, creating new, very different habitats (e.g., abiotic processes and changes in biotic communities). The U.S. Geological Survey monitors volcanic activity in many of the U.S.	Volume, temperature, and chemistry of volcanic gases, eruption frequency, periodicity and products, seismic activity, changes in magma composition, volcano deformation (e.g. GPS measurements),
Hillslope Features and Processes	landslides, rockfalls, avalanches, creep, seismicity, snow avalanches	Measurement of hillslope processes over time can give an indication of environmental stresses (deforestation, road building, and weather extremes) and provide important insights into landscape and ecosystem changes. Geologic features created by hillslope processes can be caused by natural processes (erosion, freeze–thaw cycles, climate change, faulting) and / or human actions (construction of roads and structures, agricultural practices, logging, quarrying, vibrations, drainage from pipes, culverts, mining etc.).	Mass movement of rock, debris and sediment may take place suddenly (debris and snow avalanches, lahars, rock falls and slides, debris flows) or more slowly (slumping, creep, solifluction). Human activities can accelerate or slow the natural rate of hillslope processes, wildfires can promote mass movements by destroying vegetative cover, and climate change can indirectly affect the rate and magnitude of hillslope processes.	Surface displacement; location, area, rate, frequency, and magnitude of movement; feature characteristics; area, extent, and density of features
Stream (fluvial) Features and Processes	stream channel shape, morphology, substrate, stream flow, and sediment regime (timing, duration, and pattern of flows)	<p><u>Key legal mandates:</u> Clean Water Act, Rivers and Harbors Act – Section 10, Executive Order 11988 - Floodplain Management, NPS Director’s Order 77-2 – Floodplain Management, Management Policies §4.6.6.</p> <p>Rivers are dynamic systems that are subject to rapid changes in channel shape and pattern, streamflow, sediment transport, and sediment storage. Changes in these stream processes can indicate changes in land-use or watershed conditions. An understanding of stream morphology, discharge, and stream sediment storage and load can help document channel response</p>	Stream processes play a key role in regulating and maintaining biodiversity. The physical component of a functioning aquatic ecosystem includes complex habitats and consists of floodplains, streambanks, channel structure, and flowing water. These features are created and maintained by stream channel processes and are influenced by watershed condition and health. The physical, hydraulic, and chemical properties of streams and rivers determine their suitability as habitat for aquatic species (fish, wildlife, amphibians and macroinvertebrates) and can also affect riparian vegetation and habitats. For	Channel width, depth, and gradient; sinuosity; channel cross-section; longitudinal thalweg profiles (pool frequency and depth, riffle lengths; suspended sediment and bedload transport, particle size distribution, amount and distribution of large woody debris; stored sediment in stream channel, streamflow rates

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		to human induced environmental changes such as agricultural practices, mining, dredging, logging, roads, and urbanization. For example, changes in sediment yield can reflect changes in basin conditions, including soil quality, erosion rates, vegetative cover, and hillslope stability. Watershed disturbances such as floods, fire, and land uses can significantly alter the sediment supply to streams. In turn, fluctuations in sediment discharge affect many ecosystem processes both biotic and abiotic. Nutrients are transported with the sediment load. Higher suspended sediment loads and turbidity directly affect aquatic organisms and higher sediment transport can impact the quality of stream habitat and riparian systems.	example, fluctuations in sediment load directly affect stream habitat. Salmon and steelhead require clean gravels for spawning and egg survival, juveniles need complex stream habitat (pools and riffles), good water quality and cover for protection from predators provided by overhanging vegetation, undercut banks, submerged logs, and rocks. Long-term monitoring of basic stream attributes can be used to document trends in stream channel conditions, channel response to large disturbance events, and be used to measure recovery. Physical and biological monitoring of stream systems should be integrated.	
Lake (Lacustrine) Features and Processes	lakes, sedimentation, water levels, sediment sequence and composition, outlet stability, water quality, glacial lakes, lake clarity	Lakes are dynamic systems that are sensitive to climate change and land-uses in the surrounding landscape. Lake level fluctuations and analysis of isotopes, fossil pollen, spores, and seeds in lake sediments can provide a detailed record of climate and vegetation change. Lake sediments preserve a record of past or ongoing environmental processes and components, both natural and human induced, including soil erosion, mass wasting, air-transported particulates, and contaminants from a variety of land uses. Lakes can also be a valuable indicator of near surface groundwater conditions.	Sediment deposition is a natural process that can be strongly influenced by human activities (e.g., land clearing, agriculture, deforestation, acidification, eutrophication, industrial pollution, fire, and diseases) within a watershed. Lake sediments preserve the chemical, physical, and biological composition in a chronologically ordered and resolvable record of physical and chemical changes through their mineralogy, structure, and geochemistry.	Water quality and chemistry (turbidity, temperature, pH, conductivity, pollutants, chlorophyll etc.), sediment size distribution and chemistry, macrofossils and pollen content, shoreline erosion rates
Coastal / Oceanographic Features and Processes	beaches, bluffs, dunes, rocky coasts, maritime forest, barrier island, salt marsh, tide pools, estuaries, bays, inlets, shoreline position, relative sea level, shoreline composition, sediment sequence and composition	<p><u>Key legal and policy mandates:</u> Executive Order 11988 – Floodplain Management, NPS Director’s Order 77-2 – Floodplain Management, Executive Order 11990 – Wetland Protection, Executive Order 13158 - Marine Protected Areas, Director’s Order 77-1 – Wetland Protection, Rivers and Harbors Act – Section 10, Coastal Zone Management Act, NPS Management Policies – §4.6.4., §4.6.5, §4.8.1.1.</p> <p>Erosion and accretion of shoreline deposits and relative shoreline position are important factors in determining ecosystem health and appropriate land uses in coastal</p>	Subtle changes in sediment supply, physical processes, and anthropogenic impacts can shift the balance between shoreline stability and accretion or shoreline erosion. These shoreline changes may have significant implications for coastal ecosystems, human settlements, and land uses. Relative sea level variations may be natural responses to climate change, geoidal variations, movements of the seafloor, and other earth processes and responses to human actions including draining wetlands, and groundwater withdrawal.	Temporal and spatial changes in coastal features (beach profiles, shoreline position, edge and toe of cliff, bluff, dunes and berms), topography and bathymetry, hazard zones, sediment/substrate characteristics (chemistry, mineralogy, source, nearshore sediment transport rates, shoreline erosion/accretion rates), beach nourishment and dredging, shoreline engineering, wave and current dynamics (height, period, direction), relative

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		areas. Human activities such as dredging, beach mining, river modifications, installation of coastal barriers (breakwaters, groins, jetties, etc.), removal of vegetation, and reclamation of nearshore areas as well as short-term storm events can significantly affect shoreline processes, shoreline position, and morphology. Changes in relative sea level may alter the position and morphology of coastlines, causing coastal flooding, waterlogging of soils, and a gain or loss of land. Changes in the shoreline position may also create or destroy coastal wetlands and salt marshes, inundate coastal settlements affect coastal structures and communities, and induce saltwater intrusion into aquifers, leading to groundwater salinization.		sealevel position, tide range, wind speed and direction
Marine Features and Processes (Submerged Resources)	reefs, channels, sand bars, shoals, hardbottom, sand waves, tidal deltas, submerged abiotic resources, coral chemistry, sedimentation, benthic habitat	<p><u>Key legal mandates:</u> Executive Order 13158 - Marine Protected Areas, Executive Order 13189 - Coral Reef Protection</p> <p>Marine ecosystems are not as well understood and documented as most terrestrial ecosystems. Physical processes drive the dynamics of the marine environment from larval recruitment to exchange of estuarine waters over a tidal cycle. Anthropogenic and climate change induced modifications of our coastal lands and waters directly impact the marine environment The health, diversity and extent of corals, and the geochemical make-up of their skeletons, record a variety of changes in marine waters. These include temperature, salinity, fertility, insolation, precipitation, winds, sea level, storm incidence, river run-off, and human inputs. Corals in coastal areas are susceptible to rapid changes in salinity and suspended matter concentrations and may be valuable indicators of the marine dispersion of agricultural, urban, mining, and industrial pollutants through river systems, and well as the history of contamination from coastal areas.</p>	Changes in sediment supply, physical processes, and anthropogenic impacts can alter the health of coral reef ecosystems or fish habitat. Relative sea level variations may permanently expose marine habitat to terrestrial forces or submerge additional lands. Altered nearshore currents and transport pathways may impact the success of larval recruitment, cause increased rates of shoreline erosion, and reduce water quality.	Sedimentation rates and composition (chemistry, mineralogy, source, backscatter), bathymetry, hazard zones (e.g. shoals, wrecks), coral reef characteristics (Sr/CA and U/Ca ratios, growth patterns, salinity, trace elements such as BA, radionuclides, P, heavy metals such as Pb and Cd), substrate (benthic) composition and temporal and spatial changes
Seismic Processes				Frequency and magnitude of seismic

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Add USGS text here				events, surface displacement
Paleontological Features	Fossils, tracks, burrows, coprolites	Paleontology is the study of ancient life and encompasses all of the kingdoms of life. Fossils – the preserved remains of life found in the rock record – are divided into body and trace fossils, body fossils are the direct evidence of the actual physical remains of past life and trace fossils are indications of activity and include tracks, burrows, gnaw marks and coprolites. The chances for preservation of a body fossil are greater if there are hard parts such as skeleton or a shell but under special circumstances soft tissues may be preserved. There are many ways a plant or animal may be preserved as fossil depending on the circumstances of their burial. The different types of preservation may provide important clues about the circumstances under which they lived or died.	<p>Fossils are the only direct evidence about the history of life on our planet. The geological context in which a fossil is found is often as important as the fossil itself if a paleontologist is to understand the history of life and how it has responded to environmental changes. The science of paleontology looks at relationships between different groups of organisms, how they evolved, ancient ecosystems, adaptations and the origins and extinctions of groups. In some cases paleontology is closely tied to economic aspects of geology such as increasing our knowledge about coal and oil and how they are formed.</p> <p>In order to minimize adverse impacts to paleontological resources it is important to inventory the geologic formations that may contain fossils, and to protect these areas during ground disturbing activities in the park. Once paleontological sites are identified, it is important to monitor the sites using standard monitoring protocols to ensure their long term protection.</p>	Erosion rates